THE HYDROGEN-ION CONCENTRATION OF THE SOIL IN RELATION TO FLORA AT SQUIRE VALLEEVUE FARM

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The intensive study of the relation of the hydrogen-ion concentration of the soil to plant growth has developed mainly within the last twenty years. Gillespie (7) was the first to use the hydrogen electrode on an extended scale as an indicator of reaction in soils. The use of this method, which is now generally accepted as indicating soil acidity or alkalinity, has been based on the assumption that the only direct explanation of soil acidity is the presence of the hydrogen-ion.

Much of the work on soil reaction has been carried out in cultivated soils. Weir (17) presents a table on soil reaction in relation to growth of economic plants. However, there have also been many papers dealing with the acidity and alkalinity of natural soils. Salisbury (13) points out that the hydrogen-ion concentration varies not only with the degree of leaching and organic content but also according to the source of the organic material and the phase of its decomposition. According to Atkins (2) the underlying rock or the rock from which the soil was derived also affects soil acidity.

Wherry (18) was one of the first investigators to study natural plant distribution from the point of view of the hydrogen-ion concentration of the soil. He and two other independent investigators, Arrhenius (1) and Olsen (12), came to very similar conclusions at approximately the same time, describing a surprising correlation between many plant species and hydrogen-ion concentration. Other investigators, notably Salisbury (13), Kelley (8), Kurz (10) and Cain (3), have also found a high correlation between pH and distribution of many flowering plants. The viewpoint that it is the sole factor in plant distribution has practically disappeared. Geisler (6) has pointed out that many herbaceous flowering plants of the forests tolerate a wide pH range. Coile (4) concluded that soil reaction was probably an unimportant factor in the distribution of seven forest types with which he worked. On the other hand, Shear and Stewart (14) stated that certain species of trees were found to have a fairly characteristic pH.

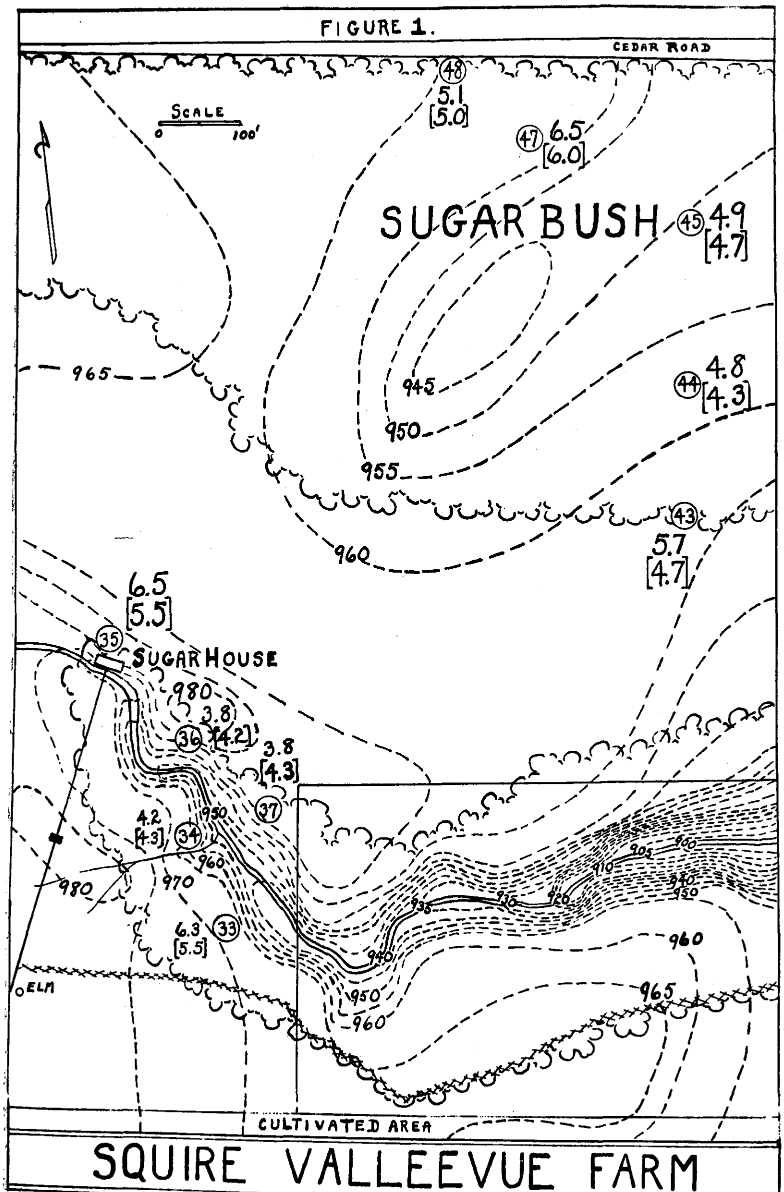

Fig. 1. General topography of Squire Valleevue Farm.

Waksman (15) was among the first to realize the significance of soil fungi in relation to soil reaction and growth of higher plants. Coleman (5) states that fungi occur in large numbers in soil rich in humus and of a high acid reaction. The work of Kopeloff (9), Salisbury (13) and Waksman (16) also indicates that the balance between the number of fungi and bacteria is determined by the reaction of the soil.

While there has been a considerable amount of work done on the separate phases of the problem, there has been very little done on the interrelationships between the reaction of the soil, the microflora and the distribution of higher plants in uncultivated areas. Morrow (11) found that her results supported the idea that the soil reaction and microflora are edaphic factors of consequence in relation to the plant cover and to the character of the soil.

The correlation of soil reaction and plant distribution, including both the microflora and the higher plants, was studied for a given uncultivated area within Squire Valleevue Farm in Cuyahoga County, Ohio. Since this correlation is based on many complex interrelationships it was naturally impossible to consider all of the factors involved so that definite conclusions might be reached. However, the results of this work seem to indicate that there is some correlation between the hydrogen-ion concentration of the soil and natural plant distribution.

There are two main considerations in connection with this general problem. First, it is essential to know the variability of the soil reaction in relation to other edaphic factors. These factors include elevation, drainage, moisture content, organic content, soil type, and soil gradient. Second, it is essential to know the types of plants within this area and their distribution in relation to the soil reaction. The higher plant forms are considered separately from the microflora because of the different methods involved in the study of each.

The area which was investigated is approximately 21 acres in extent and is well wooded. Figure 1 shows the contour lines and the general topography of the area. The underlying bedrock consists of sandstone and shale and the soil is a type of clay loam which is known to be acid and markedly deficient in lime carbonate. The layer of humus overlying the clay loam varies from one to four inches in depth. The soil has never been cultivated as far as it was possible to determine.

In the northern part of the area is an old sugar bush which represents a typical beech-maple climax community. Along

TABLE I

VARIATION IN SOIL REACTION

Station	Depth in Inches	pH Fresh Soil October	pH Oven-dried 103° C.	pH Fresh Soil April	Percentage Loss on Ignition
1	0–1	4.4	4.4	3.9	66.20
	9–10	4.6	4.6	4.6	6.60
2	0–1	5.0	4.8	4.7	4.85
	9–10	4.9	4.7	4.5	.98
3	0–1	4.2	3.6	3.7	67.81
	9–10	4.5	4.4	4.5	6.50
4	0–1	4.7	4.3	4.5	23.15
	9–10	4.8	4.5	4.6	8.00
5	0–1	4.4	4.2	4.4	25.13
	9–10	4.5	4.5	4.4	11.64
6	0–1	5.3	5.5	5.2	6.76
	9–10	5.8	5.5	5.6	2.99
7	0–1	4.3	4.1	4.2	28.50
	9–10	4.2	4.2	4.3	5.37
8	0–1	3.7	3.7	3.8	61.87
	9–10	4.1	4.2	4.1	13.06
9	0–1	4.2	4.1	4.2	83.94
	9–10	4.5	4.5	4.6	7.46
10	0–1	3.7	3.7	4.4	39.62
	9–10	4.3	4.3	4.5	1.70
11	0–1	4.5	4.2	4.2	14.99
	9–10	4.2	4.1	4.5	13.26
12	0–1	4.7	4.1	4.7	11.42
	9–10	4.4	4.0	4.4	7.64
13	0–1	4.5	4.2	5.1	18.64
	9–10	4.9	4.7	4.9	2.42
14	0–1	4.6	....	4.7	22.01
	9–10	4.6	....	4.6	7.46

the ravine, however, there are many hemlocks and black birches forming primarily a hemlock, beech and birch association.

It was necessary to set up soil sampling stations over the area at random, irrespective of the vegetation in order that the variability of the soil reaction might be analyzed in relation to the topography, depth, and organic content of the soil. Samples were taken at the surface (0–1″) and at the subsoil (9–10″). The hydrogen-ion concentration of the soil was determined using a quinhydrone reference electrode. The entire range of pH was from 3.7 to neutral. Practically all of the soil is distinctly acid and the degree of acidity of the soil from sampling stations only a few feet apart may vary more than 0.5 pH.

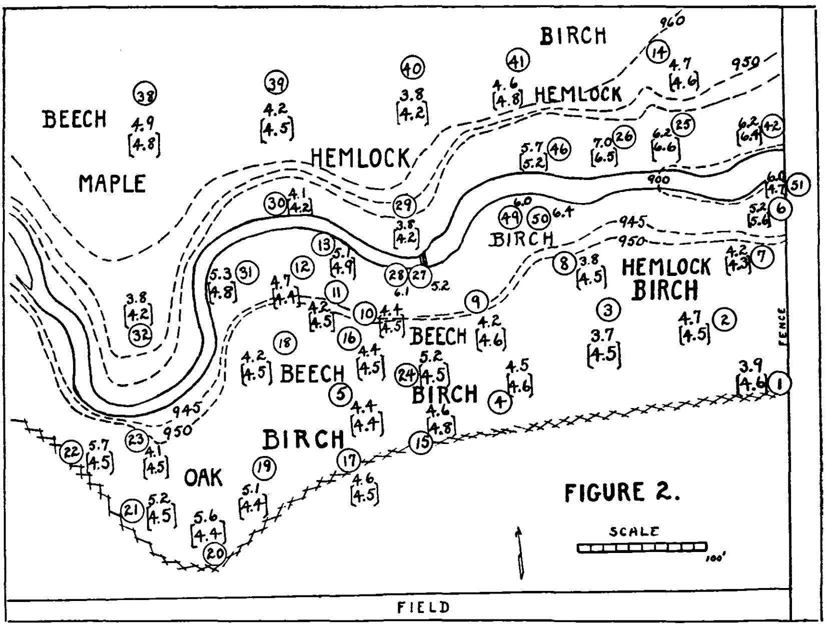

Fig. 2. The pH of the soil in relation to the topographical features of the farm.

However, a certain amount of variability is expected and reasons for large differences in pH may usually be assigned to such factors as organic content, leaching, or plant cover.

Data on the soil from 14 of the sampling stations are shown in Table I. It gives a comparison of the pH of the soil obtained in the fall when it is moist and when it is dried in an oven at 103° C. for at least six hours. The results seem to show that drying soil at high temperatures slightly increases the acidity of the soil, and the change may depend upon the original pH and type of soil. The table also shows the variations between the fresh soil collected in October and that obtained

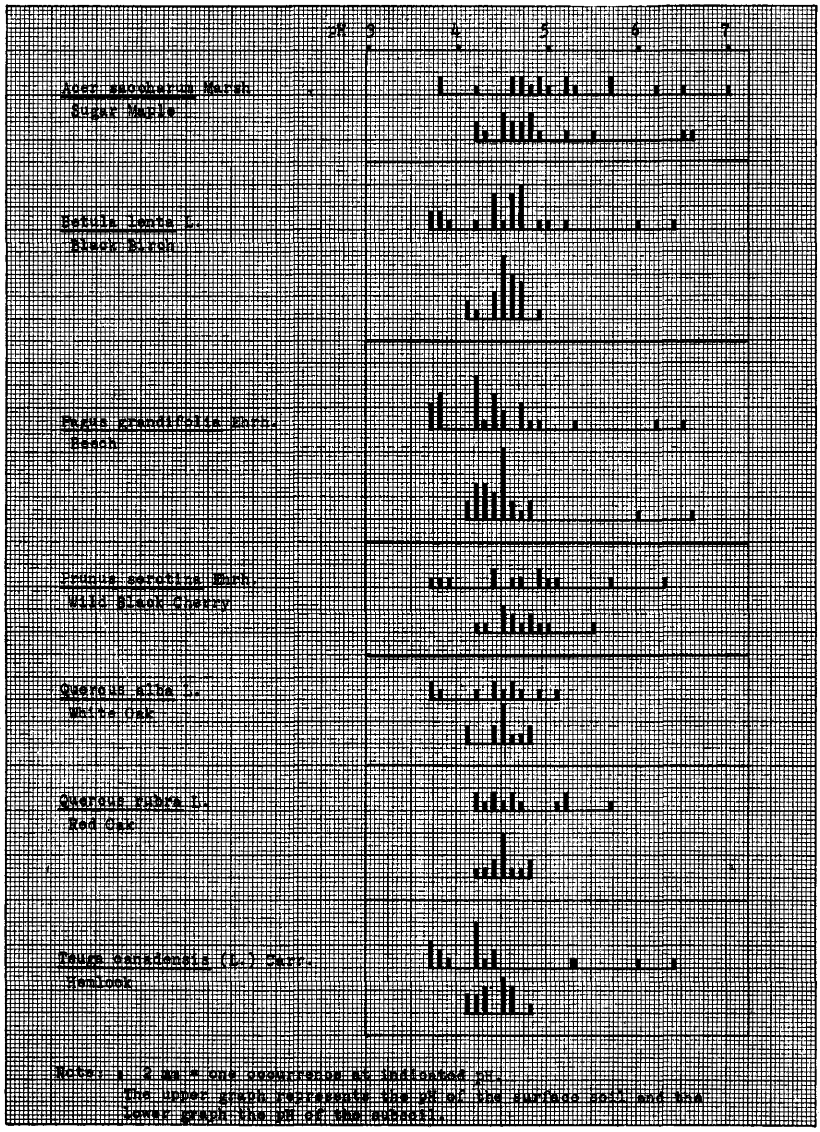

Fig. 3. Frequency distribution and pH range of trees.

in April, but no conclusions could be made from this data to indicate that the hydrogen-ion concentration of the soil might be definitely greater in one of these seasons. The percentage loss on ignition has been considered as roughly indicating the

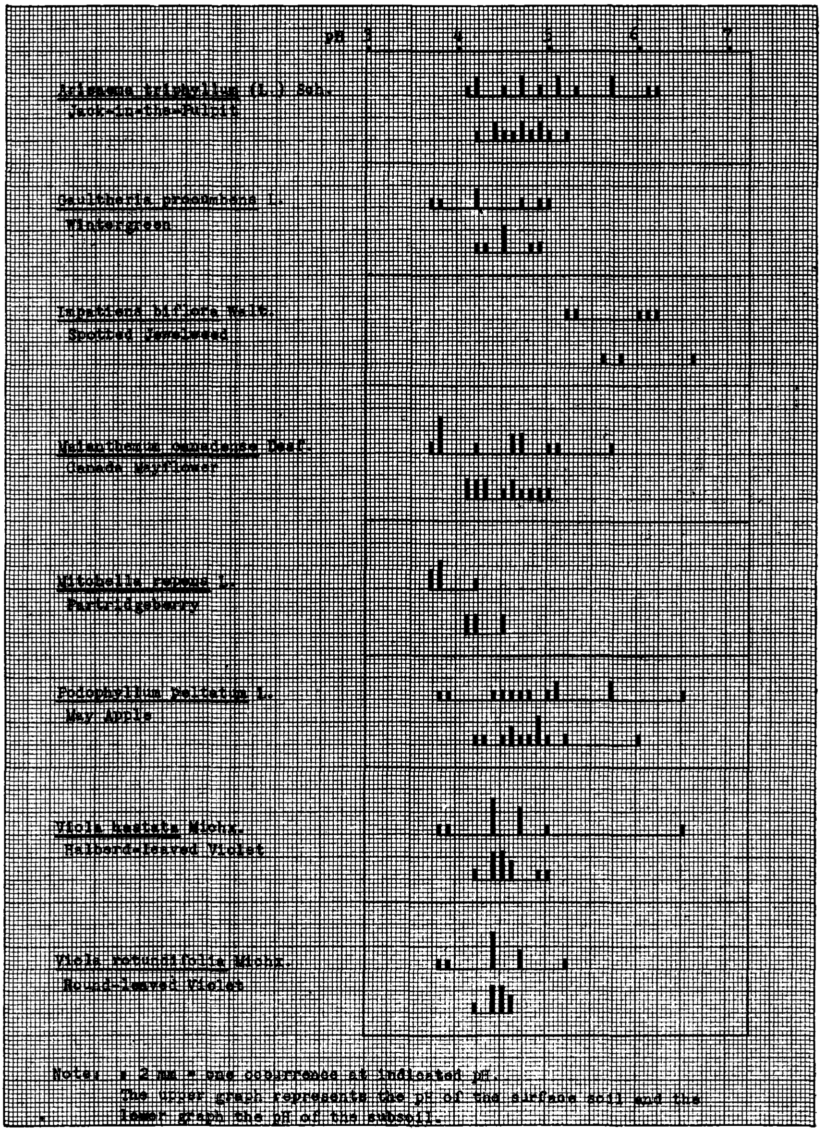

Fig. 4. Frequency distribution and pH range of flowers.

organic content of the soil. The results show a consistently higher percentage of organic matter in the surface soil than in the subsoil as was expected. While there is no consistent correlation between the percentage of organic matter and the degree of acidity, yet there is evidence that the acidity increases with the organic content of the soil.

The pH of the soil in relation to topographical features and general plant cover is shown in Figure 2. The number of the soil sampling station is indicated in the circle. The map shows the pH of the surface soil at each station and that of the subsoil in parenthesis. First it is evident that the most acid soil is along the upper edge of the ravine. It is most densely wooded in this area and consequently the organic content of the soil is very high. It is possible that leaching may play a role in determining the soil acidity since the acidity tends to decrease with the slope. The plant cover is definitely a factor in determining the soil pH, particularly at the surface. The soil is most acid underneath the hemlocks where needles tend to keep the pH at the surface layer very low. Most of the hemlocks are along the upper edge of the ravine and therefore tend to keep the acidity in this area quite high. Only a few hemlocks are growing at the bottom of the ravine or near the edge of the woods. At Station 1 the lone hemlock apparently lowers the pH of the soil in the immediate vicinity to 3.9. The subsoil under the hemlocks is less acid than the surface soil in all cases. Despite the relatively high organic content of the soil beneath the birch and beech, the surface layer tends to be slightly less acid than the subsoil. This could be explained according to the theory of Salisbury (13) who believes that the complete removal of bases from the surface is retarded because of the high calcium content of the leaves of these trees.

The correlation of soil reaction and plant distribution may be shown by means of graphs that indicate both the pH range and the frequency distribution of most of the trees, shrubs, flowers, ferns and mosses within a few feet of each sampling station. The common species of trees shown in Figure 3 have fairly representative frequency distribution graphs. Such trees as the sugar maple, black birch, beech, black cherry, red oak, white oak and hemlock show a fairly wide pH range with an apparent optimum range in which they are most abundant. The sugar maple, for example, shows a pH range in the surface soil from 3.8 to neutral, with an optimum pH range from 4.6 to 5.7. The black birch shows a range from 3.7 to 6.4 with an optimum range from 4.4 to 4.7. Beech shows a range from 3.7 to 6.5 with an optimum range from 3.7 to 4.7. The two species of oak show a narrower pH range than some of the other common trees. The hemlock seems to have a fairly wide range of reaction tolerance from 3.7 to 6.4, but was found most commonly in soil which was very acid, from 3.7 to 4.4. The subsoil in each case shows a similar optimum pH range for each tree but the range is narrower than that of the surface soil.

The frequency distribution and pH range of some of the common flowers in the area are shown in Figure 4. On the whole, the flowers that were studied showed less reaction tolerance than the trees. These graphs confirm the general observation that plants such as wintergreen, partridgeberry and Canada Mayflower tend to grow in more acid soil than such plants as jack-in-the-pulpit and spotted jewelweed. Again there is an indication that plants may have a fairly wide pH range and a more limited optimum pH range. For example, the halberd-leaved violet shows a range from 3.8 to 6.5 but it was found more frequently in soil from pH 4.4 to 4.7.

The study of the microflora of the soil in relation to the soil reaction required quite a different technique. The relative abundance of molds and bacteria in relation to soil reaction was determined by the plate method. The results showed that in the general count of microflora within the wooded section immediately south of the ravine the bacteria far outnumbered the molds per gram of soil both at the surface and the subsoil. However, in very acid soil with a pH of 3.8 the molds outnumbered the bacteria at the surface layer. In the subsoil with a pH of 4.1, the number of bacteria per gram of soil exceeded the count of the molds considerably. Edaphic conditions such as moisture content and aeration undoubtedly are other factors in determining the count of microflora.

SUMMARY

Variability of the soil reaction apparently depends to a considerable extent on the amount of organic material, the degree of leaching, and the plant cover. The soil was most acid under the hemlocks and least acid under beech and birch. The majority of plants studied showed a fairly wide range, within certain limits, of reaction tolerance. The herbaceous plants appeared to be somewhat more sensitive to soil acidity than the trees as a group. Of the microflora, the molds were more acid tolerant than the bacteria in soils with a pH less

than 4.0. In general the results of the study seem to verify the opinion that while the hydrogen-ion concentration is not the sole factor in plant distribution, it is, at least, one of considerable importance.

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Fig. 5. View of the ravine section at the waterfall showing the bedrock formation of shale and sandstone. The hemlock in the foreground was the only one found growing in a soil with a pH of 6.0 to 6.4. It was the only hemlock of any size growing at the bottom of the ravine.